

## NSRL Results and Future Plans for Space Research

by

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The NASA Space Radiation Laboratory (NSRL) was commissioned in 2003 as a state-of-the-art facility to enable research for understanding and mitigating space radiation effects on astronauts. Radiation exposures in space occur under chronic conditions with a large number of nuclei and energies contained in the galactic cosmic rays (GCR) or solar proton events (SPE). In the first five-years of the NSRL, a large number of mono-energetic beam studies simulating space radiation components have been made with H, C, O, Si, Cl, Ti, and Fe nuclei at several energies and more limited studies were made with fractionated p and Fe exposures.

We review recent NSRL science results and describe future needs to extend and improve NSRL's space radiation simulation capabilities. Late effects from space radiation develop in relationship to several characteristic time scales and experimental models carry limitations in which of these can be studied in a practical manner and on how results can be extrapolated to humans. Biological time scales must be considered in relationship to the dose-rates and exposure durations of interest in planetary exploration. The potential responses of cell culture or animal models to diverse spatial and temporal energy deposition components from mixtures of protons and heavy ions of different energies are discussed. Studies with multiple ion types and energies will be needed to simulate the planetary surface environments expected on the moon or Mars, where a largely CO<sub>2</sub> atmosphere and diverse surface materials produce a Mars specific mixture of primary and secondary radiation components. Such studies will benefit from the new Electron Beam Injector Source (EBIS) at BNL beginning in 2011, however will require optimization on the ion components and energies used in the simulation to best represent conditions on the Mars surface. As NSRL research achieves reductions in uncertainties in risk projections, biomedical countermeasure requirements for planetary exploration will become known.

We describe possible drug discovery and testing regimes that are envisioned for the second phase of NSRL research in the period from 2016 to 2025 in anticipation of the human exploration of Mars mission in 2030. In addition, albeit biological uncertainties currently obscure potential differences in radiation shielding materials, new knowledge will lead to revised considerations of shielding materials. The optimized testing regimes used for biological countermeasure research should be exploited for materials testing programs in the future.